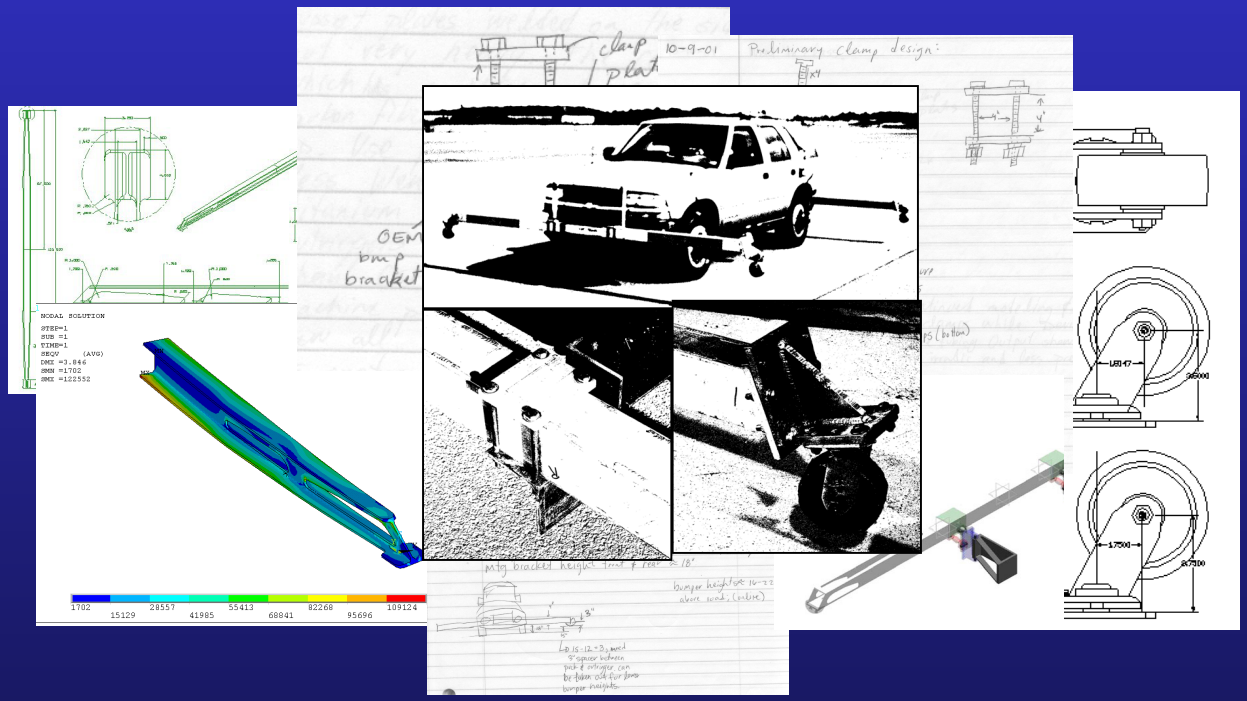
Effects of Outriggers on Dynamic Rollover Resistance Maneuvers



Results From NHTSA's Light Vehicle Rollover Research Program

Devin Elsasser
Transportation Research Center Inc.
Garrick Forkenbrock
National Highway Traffic Safety Administration

NHTSA
People Saving People
http://www.nhtsa.dot.gov

Presentation Overview

People Saving People
http://www.nhtsa.dot.gov

- **Introduction**
  - Dynamic testing
  - Objectives
- **Test Matrix**
  - Vehicles
  - Maneuvers
  - Outriggers
- **Testing Locations and Conditions**
  - Location
  - Ambient Conditions
- **Test Equipment**
  - Vehicle configuration, Instrumentation and tires
  - Comparison of three outrigger types
- **Test Results**
  - Results from VIMF data
  - Results from dynamic testing
- **Discussion of Results**
  - Observations from dynamic testing
- **Conclusions**

Introduction

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **Dynamic Testing**
  - Essential part of the rollover-rating program
  - Mandated by TREAD Act
  - Severe nature of tests require outriggers for driver safety
- **Objective of Outrigger Study**
  - Preserve driver safety
  - Evaluate outriggers with different weights and inertias
  - Determine the extent to which different outrigger designs influence test results of J-Turn and Road Edge Recovery test maneuvers

Outrigger Criteria

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **Design criteria**
  - Minimize weight of outriggers
    - Reduces center of gravity influence
  - Minimize roll inertia
  - Lower pitch and yaw inertias
  - Outrigger height adjustability
  - Straight forward installation
- **Center mount versus front and rear mounted outriggers**

Test Matrix

People Saving People
http://www.nhtsa.dot.gov

- **Test Vehicles**
  - 2001 Chevrolet Blazer 4x2
  - 2001 Toyota 4Runner 4x4 (VSC disabled)
  - 2001 Ford Escape 4x4
  - 1999 Mercedes ML320 4x4 (ESP disabled)
- **Outriggers**
  - Aluminum Outriggers
  - Titanium Outriggers
  - Carbon Fiber Outriggers
- **Maneuvers**
  - Slowly Increasing Steer
  - NHTSA J-Turn
  - NHTSA Road Edge Recovery
- **More Maneuver and Vehicle Information**
  - In NHTSA Phase IV report

Testing Locations and Conditions

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **Inertial Measurements**
  - S.E.A. Inc. – Columbus, Ohio
    - –VIMF (Vehicle Inertial Measurement Facility)
- **Dynamic Testing Location**
  - TRC Inc. – East Liberty, Ohio
- **Ambient Conditions**
  - 36 to 71 °F

Test Equipment

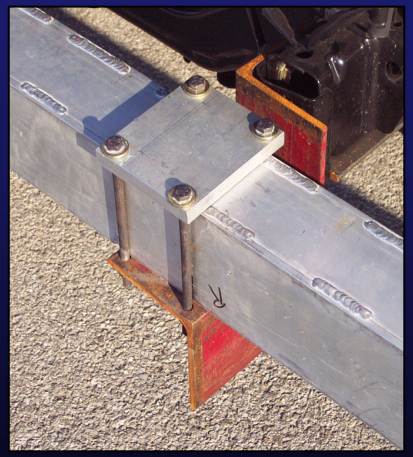
People Saving People
http://www.nhtsa.dot.gov

- **Test Vehicle Configuration**
  - Nominal Load
  - Equipped with instrumentation
    - Further details in Phase IV report
  - Steering Controller
    - Mounted to steering wheel
    - Electronics box placed in rear seat footwall
- **Tires**
  - New, same make model, size and DOT specification as supplied from manufacturer
  - Pre-conditioned with 100 miles of initial service
  - Inner tubes used in tires for Road Edge Recovery Maneuver

Outriggers
NHTSA Aluminum Outriggers

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **Designed at VRTC**
- **Lowest cost**
- **Can be produced in-house**
- **Height adjustment**
  - End of outrigger
  - Mounts
- **Castor wheels**
- **Weight**
  - 78 lbs per outrigger (excluding mounts)



Outriggers
Carbon Fiber Outriggers

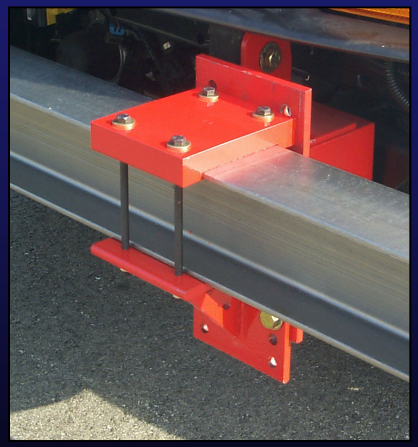
NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **Carr Engineering**
- **Highest cost**
- **Height adjustment**
  - Mounts
- **Load capacity**
  - 3900 lbs vertical load
- **Castor wheels**
- **Weight**
  - 58 lbs per outrigger (excluding mounts)

Outriggers
NHTSA Titanium Outriggers

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **Designed at VRTC**
- **1/3 cost of carbon fiber**
- **Height adjustability**
  - Mounts
- **Load capacity**
  - 3900 lbs vertical load
  - 1200 lbs friction load
- **Low-mu hemispherical skid pads**
- **Weight**
  - 63 lbs per outrigger (excluding mounts)



Static Test Results
VIMF

NHTSA
People Saving People
http://www.nhtsa.dot.gov

Effect of Outriggers on Static Parameters

1 = least effect 3 = most effect

Category	Carbon Fiber	Titanium	Aluminum
Outrigger Weight	1 (58x2 = 116 lbs)	2 (63x2 = 126 lbs)	3 (78x2 = 156 lbs)
Roll Inertia	2 (18-24%)	1 (17-22%)	3 (21-28%)
Yaw and Pitch Inertia	1 (7-20%)	2 (8-20%)	3 (8-21%)
CG Height	1 (2-4%)	1 (2-4%)	1 (2-4%)

- Average combined bumper assembly weighs 100 lbs
- Instrumentation weighs approximately 150 lbs
- Outrigger mounts weigh approximately 100 lbs

Steering Angles

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- Slowly Increasing Steer maneuver
- Methods presented in previous presentation
- Largest difference 4.5%

Vehicle	Aluminum Outriggers		Carbon Fiber Outriggers		Titanium Outriggers	
	RER	J-Turn	RER	J-Turn	RER	J-Turn
Toyota 4Runner	309	381	313	385	304	374
Chevrolet Blazer	326	401	329	405	326	401
Ford Escape	252	310	241	296	245	302
Mercedes ML320	273	336	262	322	272	334

Dynamic Testing
Two Wheel Lift Results

NHTSA
People Saving People
http://www.nhtsa.dot.gov

Vehicle	Outrigger Design	J-Turn (mph)		Road Edge Recovery (mph)	
		Left Steer	Right Steer	Left-Right Steering	Right-Left Steering
2001 Toyota 4Runner 4x4	Aluminum	-	-	-	-
	Carbon Fiber	-	-	-	-
	Titanium	-	-	-	-
2001 Chevrolet Blazer 4x2	Aluminum	-	-	41.2	41.4
	Carbon Fiber	62.1	-	39.2	41.5
	Titanium	-	-	41.0	42.2
2001 Ford Escape 4x4	Aluminum	-	-	-	-
	Carbon Fiber	-	-	-	-
	Titanium	-	-	-	-
1999 Mercedes ML320 4x4	Aluminum	-	-	40.0	-
	Carbon Fiber	-	-	40.5	-
	Titanium	-	-	40.9	-

- Two-wheel lift = 2 in. or more of simultaneous wheel lift
- Determined from video data
- Entrance speed for which two-wheel lift was first noticed

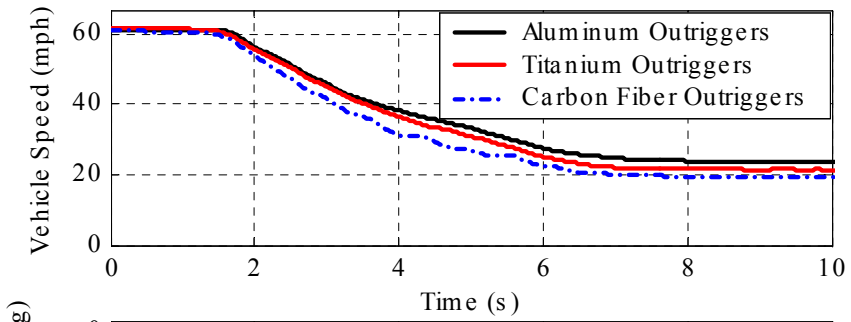
Observations
NHTSA J-Turns

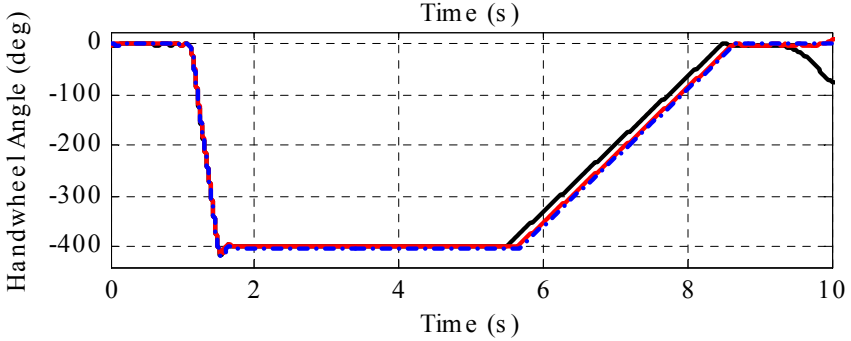
NHTSA
People Saving People
http://www.nhtsa.dot.gov

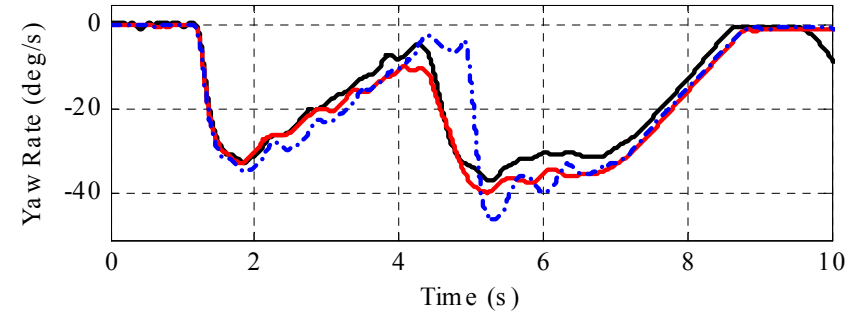
- **Chevrolet Blazer**
  - Carbon Fiber Outriggers
    - Produced two-wheel lift at 62 mph
    - Test cutoff speed at 60 mph
    - Threshold speed not known
  - Titanium and Aluminum Outriggers
    - No two-wheel lift at approximately 61 mph
  - Carbon Fiber TWL when steered to left
  - Similar responses when steered to right

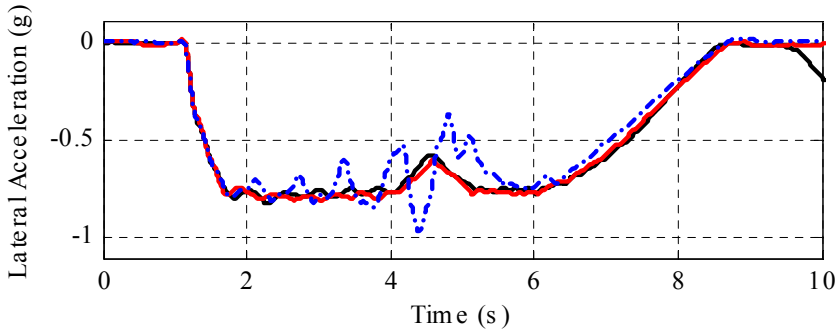
Chevrolet Blazer J-Turn Test

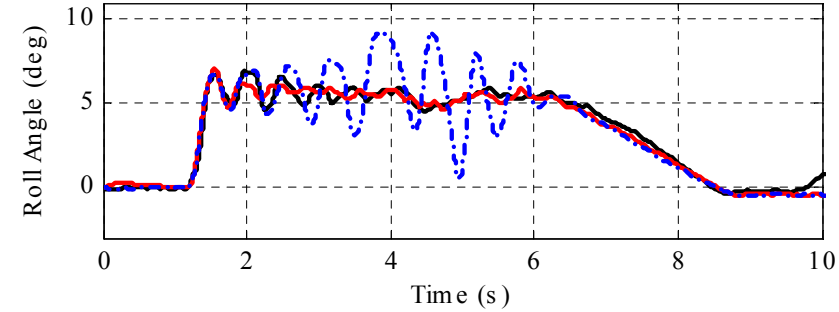
NHTSA
People Saving People
http://www.nhtsa.dot.gov

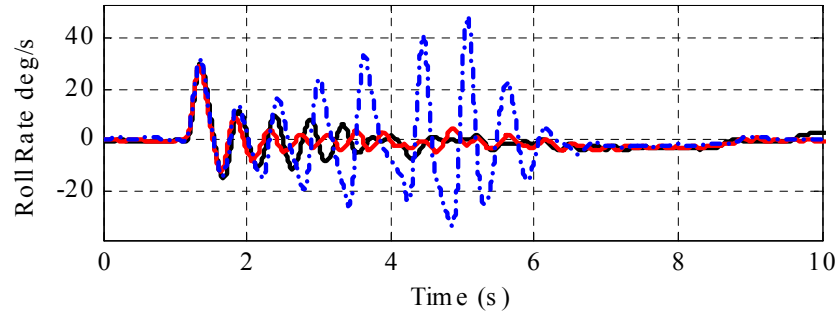












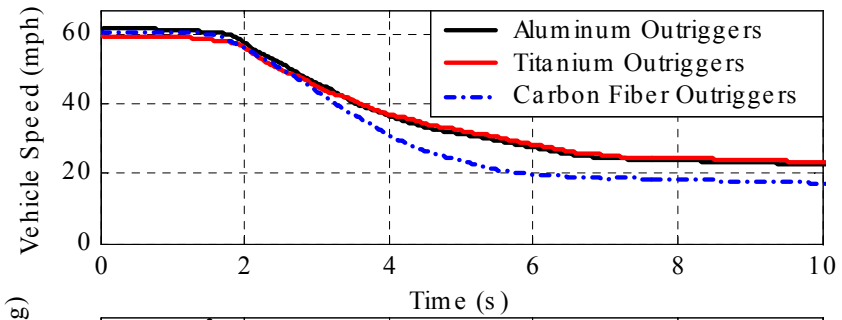
Observations
NHTSA J-Turns

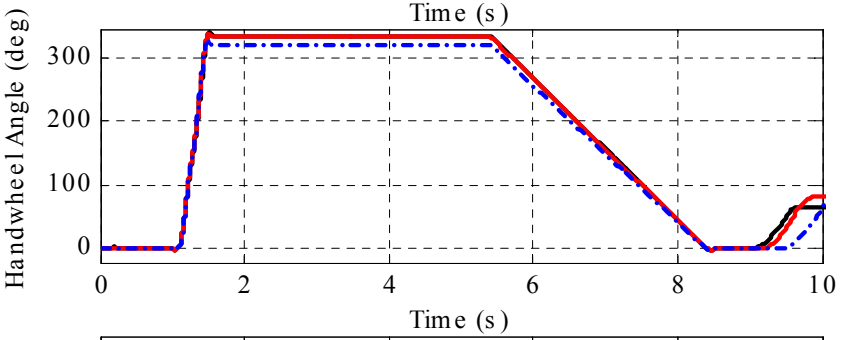
NHTSA
People Saving People
http://www.nhtsa.dot.gov

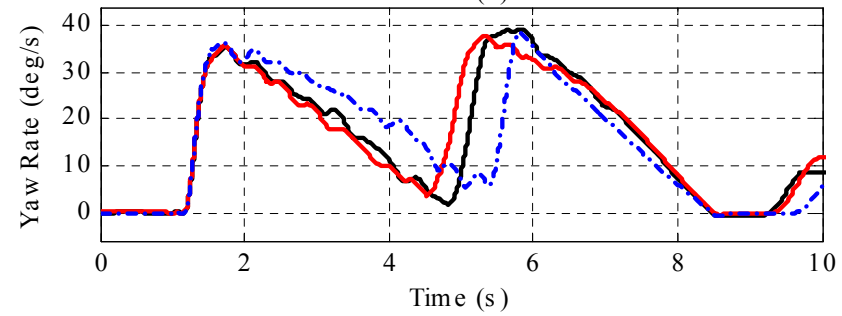
- **Ford Escape, Mercedes ML320 and Toyota 4Runner**
  - Slight differences in responses for some tests
  - Nearly identical responses in others

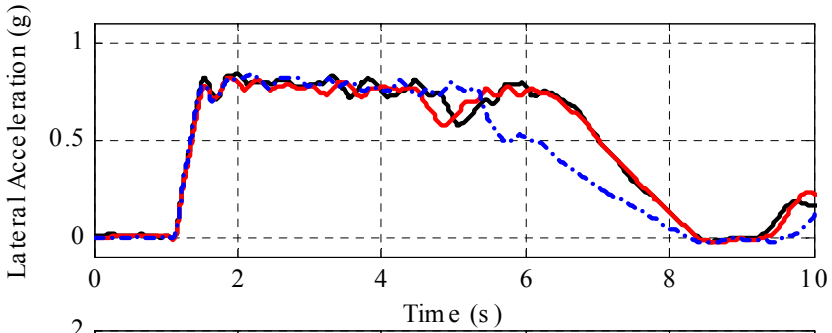
Mercedes ML320 J-Turn Test

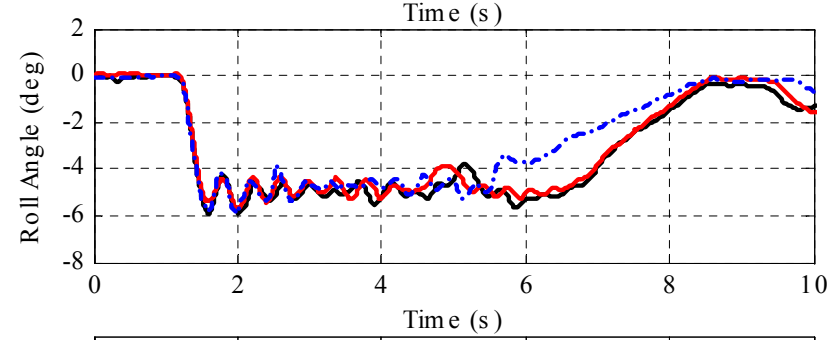
NHTSA
People Saving People
http://www.nhtsa.dot.gov

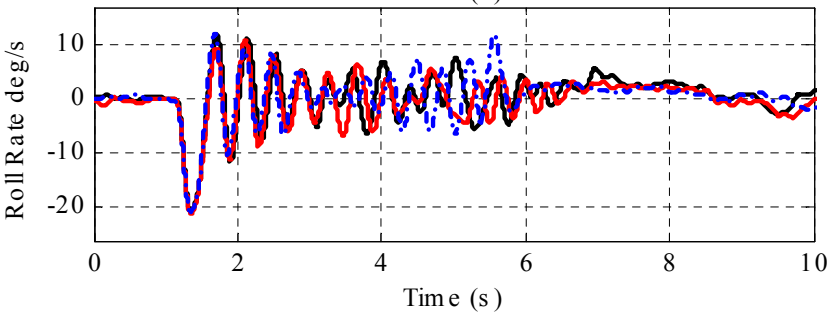












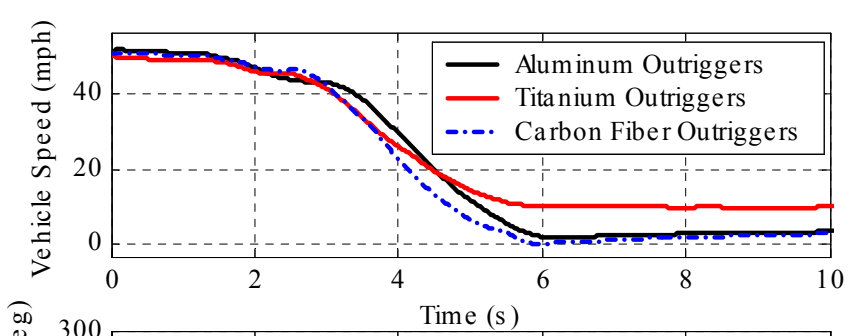
Observations
Road Edge Recovery

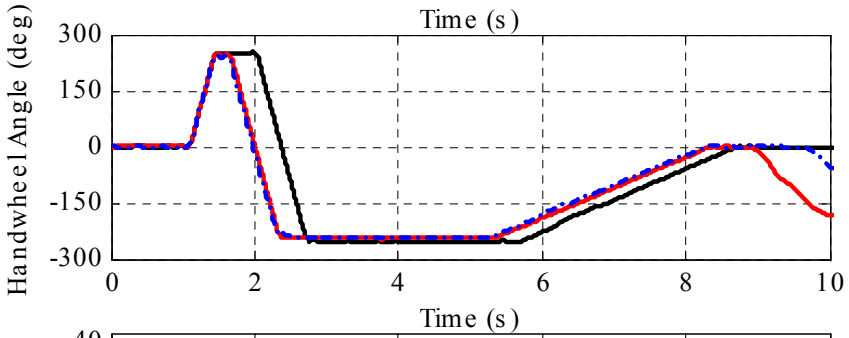
NHTSA
People Saving People
http://www.nhtsa.dot.gov

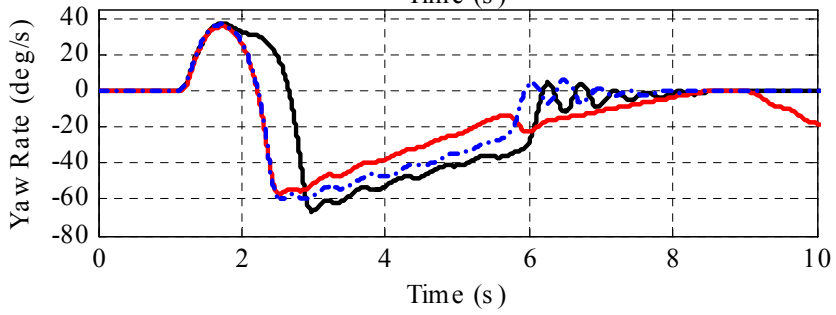
- **Roll Rate Feedback**
  - Previous presentation by Garrick
  - More details in Phase IV report
- **Ford Escape**
  - Roll responses varied as function of which outriggers were installed
  - Aluminum Outriggers
    - Extended dwell times at 40 and 50 mph

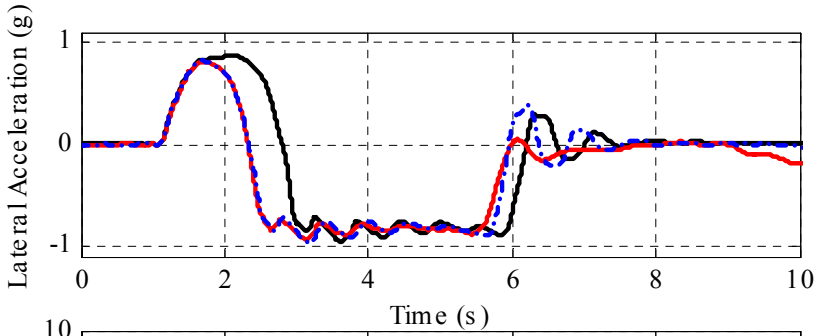
Ford Escape Road Edge Recovery Test

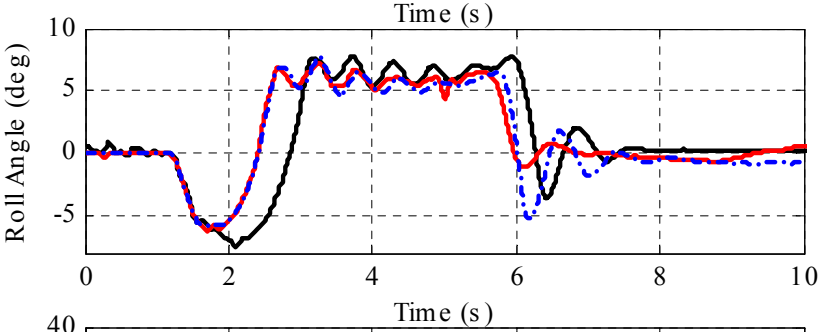
NHTSA
People Saving People
http://www.nhtsa.dot.gov

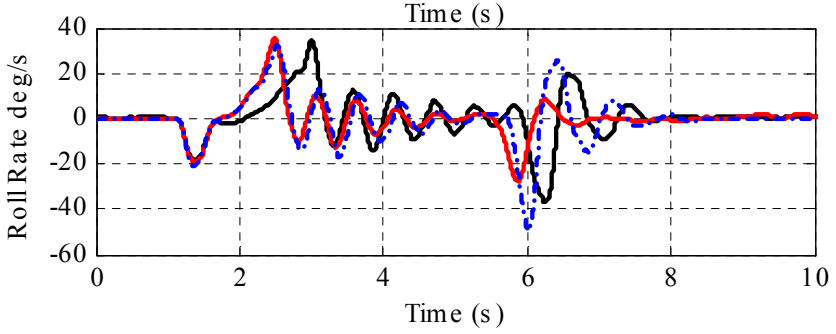












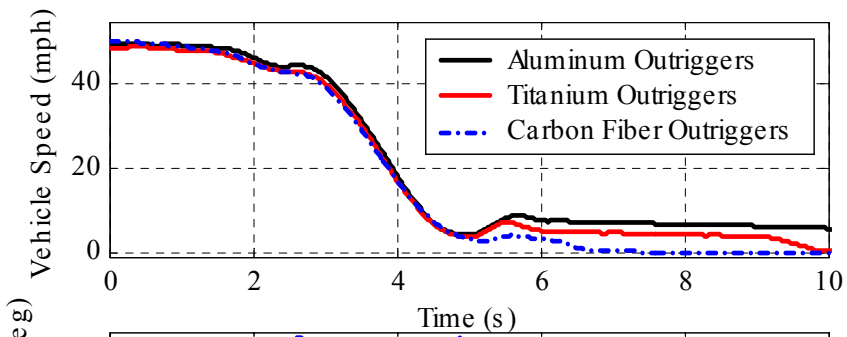
Observations
Road Edge Recovery

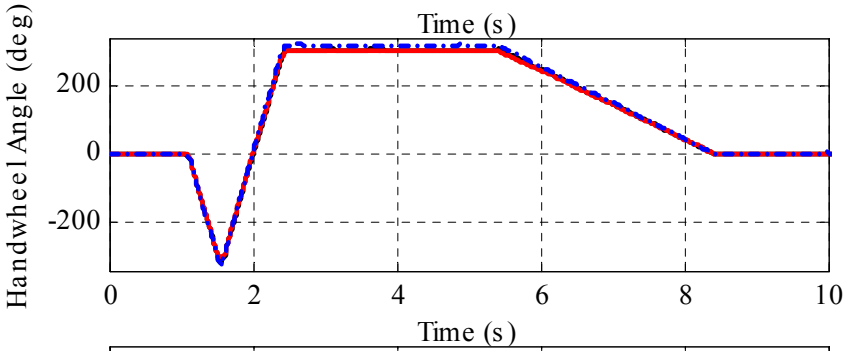
NHTSA
People Saving People
http://www.nhtsa.dot.gov

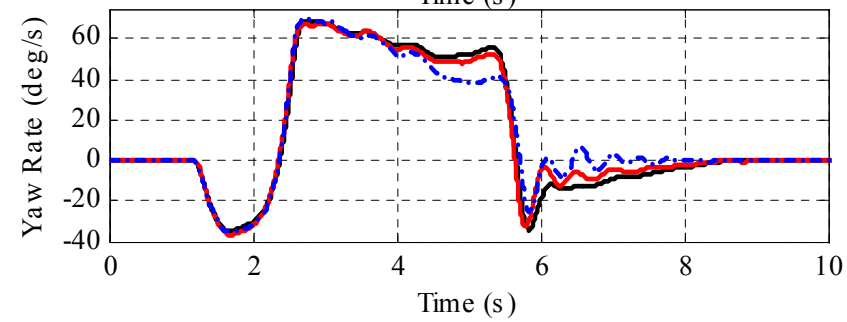
- **Chevrolet Blazer and Mercedes ML320**
  - Produced two-wheel lift with each set of outriggers
- **Toyota 4Runner**
  - Near identical responses

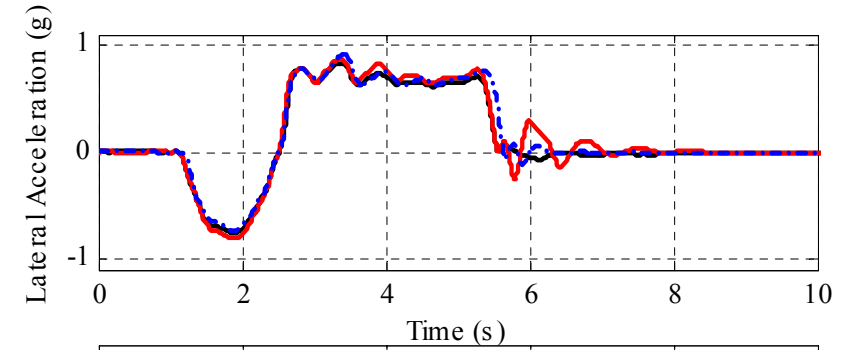
Toyota 4Runner Road Edge Recovery Test

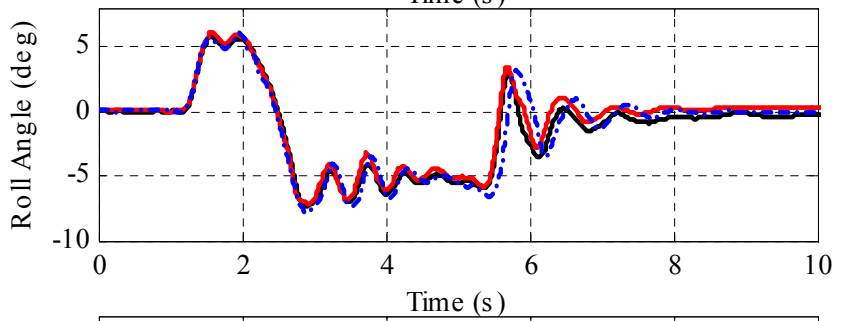
NHTSA
People Saving People
http://www.nhtsa.dot.gov

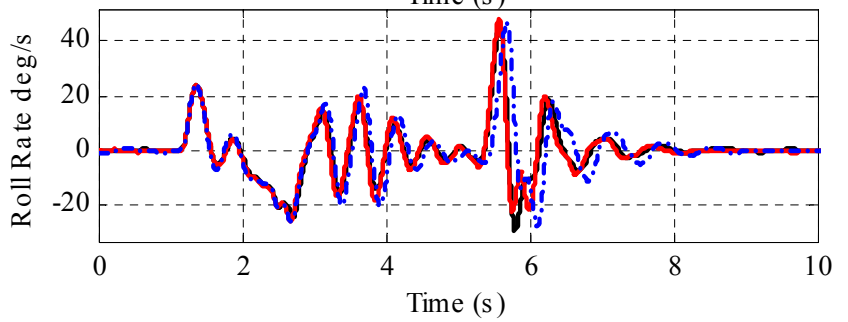












Conclusions

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **Vehicle Inertial Measurements**
  - Influenced by outriggers
  - Titanium and Carbon Fiber Outriggers have least overall influence
  - Titanium Outriggers have least roll inertia influence
- **Slowly Increasing Steer Test**
  - Outriggers had little influence on the overall average handwheel angles
  - Largest difference 4.5%

Conclusions

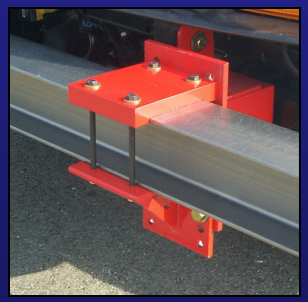
NHTSA People Saving People http://www.nhtsa.dot.gov

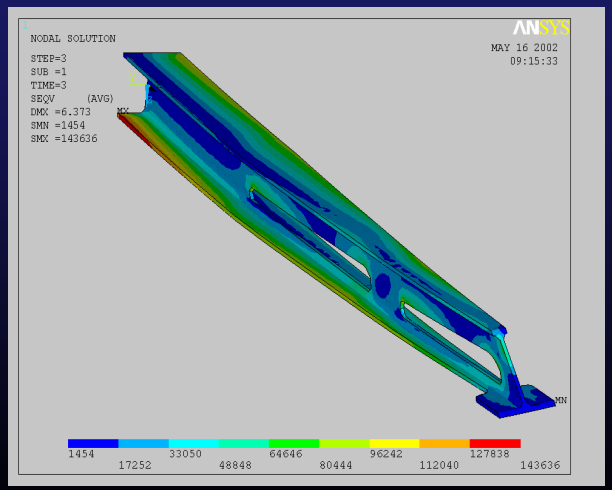
- **NHTSA J-Turn**
  - Blazer two-wheel lift
    - Not clear that two-wheel lift is related to outrigger design or testing at vehicle's dynamic threshold
  - Other vehicles
    - no pronounced trends as a function of outrigger installation
- **Road Edge Recovery**
  - Escape tests
    - Differences in dwell time
  - Blazer and ML320
    - Near identical TWL speeds regardless of outrigger installed
  - Overall
    - Responses were very similar

Titanium Outrigger Chosen As NHTSA's Preferred Outrigger

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **Highlights**
  - Safe for driver
  - Strong
  - Lowest roll inertia influence of the three designs compared
  - Cost less than carbon fiber
  - Use light-weight skid pads
  - Not much heavier than carbon fiber design

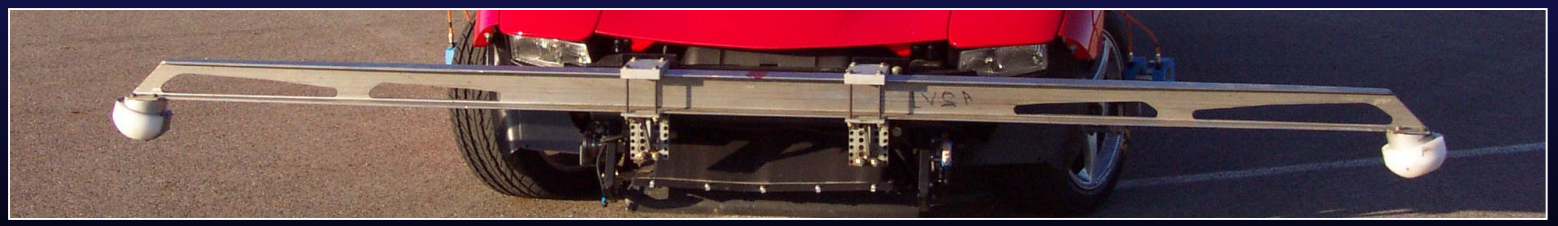




Outrigger Specifications

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **"Standard" Titanium Outrigger**
  - 3500 to 7000 lb vehicles
  - 3900 lbs vertical load
  - 1200 lbs friction load
  - 63 lbs per outrigger
- **"Short" Titanium Outrigger**
  - Vehicles less than 3500 lbs
  - 2000 lbs vertical load
  - 1200 lbs friction load
  - 58 lbs per outrigger



Available

NHTSA
People Saving People
http://www.nhtsa.dot.gov

- **In Docket: NHTSA-2001-9663-75**
  - Detailed Drawings
    - "Standard" and "Short" Titanium Outriggers
    - Mounts and skid pads
  - Outrigger CNC code
    - Files to machine exact replicas of NHTSA's "Standard" and "Short" Titanium Outriggers
- **More Information Contact**
  - John Struble
    - E-mail: jstruble@nhtsa.dot.gov
    - Phone: (202) 493-0246